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ABSTRACT

The research reported in this paper investigated the efficacy of the use of comprehensive computer-based instruction (CBI) for providing basic skills remediation to educationally disadvantaged student populations. Thirteen CBI programs placed in 26 elementary and secondary schools throughout the New York City school system were evaluated during the 1987-88 school year. Results reveal that CBI programs can indeed be an effective means for delivering such instruction, that they can be as effective in providing instruction in reading as they are in providing mathematics instruction to educationally disadvantaged students, and that within that population an inverse relationship exists between instructional level and achievement gains resulting from involvement with CBI. The differential effectiveness of differing programs was also suggested in the findings. Interviews with participating students and teachers indicate that four features of CBI make it particularly useful to educationally disadvantaged students-- CBI is perceived by students as less threatening than traditional classroom instruction, it provides extensive drill and practice exercises, it typically provides individualized diagnostics, and CBI programs provide students with greater academic support. Results of data analyses are reported in 18 tables. (14 references) (Author)

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HONING IN ON THE TARGET: WHO AMONG THE EDUCATIONALLY DISADVANTAGED BENEFITS MOST FROM WHAT CBI?

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Abstract

The research reported in this paper investigated the efficacy of the use of comprehensive computer-based instruction for providing basic skills remediation to educationally disadvantaged student populations. Thirteen CBI programs placed in twenty-six elementary and secondary schools throughout the New York City school system were evaluated during the 1987/88 school year. Results reveal that CBI programs can indeed be an effective means for delivering such instruction, that they can be as effective in providing instruction in reading as they are in providing mathematics instruction to educationally disadvantaged students, and that within that population an inverse relationship exists between instructional level and achievement gains resulting from involvement with CBI. The differential effectiveness of differing programs was also suggested in the findings. Interviews with participating students and teachers indicate that four features of CBI make it particularly useful to educationally disadvantaged students -- CBI is perceived by students as less threatening than traditional classroom instruction, it provides extensive drill and practice exercises, it typically provides individualized diagnostics, and CBI programs provide students with greater academic support.

Many authors have argued that comprehensive computer based instruction might best be used for delivering basic skills instruction to educationally disadvantaged students (Niemiec & Walberg, 1987). Not only is there a critical need for some means of addressing persistent functional illiteracy among an unacceptable percentage of the American population (National Commission on Excellence in Education, 1983; Commission on Reading, 1985; Kirsch & Jungeblut, 1986; National Assessment of Educational Progress, 1988), but research suggests that educationally disadvantaged students benefit most from the use of CBI systems (Jamison, Suppes & Wells, 1970; Chambers & Sprecher, 1980; Schmidt, Weinstein, Niemiec & Walberg, 1985; Niemiec & Walberg, 1987). Indications are also that students learn more quickly from CBI programs than from regular classroom instruction (Ragosta, 1982; Kulik, Kulik & Bangert-Drowns, 1985; Bangert-Drowns, Kulik & Kulik, 1985) and that their motivation for and attention to needed drill and practice is improved by the use of computer delivery (Electronic Learning Laboratory, 1982; White, 1986; Niemiec & Walberg, 1987). Such factors may be particularly important to educationally disadvantaged students. To date, however, no large scale, systematic investigations of the use of CBI for basic skills remediation among educationally disadvantaged student populations have been conducted.

Such is the work of the **Computer Pilot Program** of the Division of Computer Information Services of the New York City Board of Education. The Computer Pilot Program was designed to investigate the educational uses of computers, and to explore the efficacy of their use with New York City's educationally disadvantaged student population. The research reported in this paper is concerned with the statistical analyses of the effects of thirteen CBI programs on the reading and mathematics performance of educationally disadvantaged students in the third through tenth grades. It is unique in that it examines within a single study the instructional effects of a large sample of comprehensive CBI systems. It also looks at a very large educationally disadvantaged student population in many, very real, inner-city school settings.

Methodology

The Computer Pilot Program was funded by the Division of Computer Information Services of the New York City Board of Education in conjunction with the vendors (in the 1987/88 school year) of thirteen computer-based instructional systems -- **Autoskills**, **CCC**, **CCP**, **CNS**, **Degem**, **ESC**, **Ideal**, **PALS**, **PC Class**, **Plato**, **Prescription Learning**, **Wasatch**, and **Wicat**. Vendors placed their systems in appropriate schools, and offered staff development, equipment maintenance, and support at little or no cost for the evaluation period. Individual schools were responsible for staffing the programs and providing time for staff development. The Division of Computer Information Sciences provided additional equipment, technical assistance, and coordination among groups involved in the Computer Pilot Program. Evaluation of the Computer Pilot Program was carried out by the Office of Educational Assessment of the New York City Board of Education.

The goals of the Computer Pilot Program are to identify comprehensive computer-based instructional programs which can be effective in increasing the academic performance, attendance, and positive attitudes of educationally disadvantaged students, and to isolate the implementation factors significantly influencing program and/or implementation effectiveness.

During the 1987/88 school year, comprehensive CBI programs were evaluated in ten elementary, seven junior high or intermediate schools, and nine high schools throughout New York City. Most school sites were chosen by the Chancellor, and at each a program coordinator was selected by the school or the school district to be responsible for the daily operation of the program. Each school was also responsible for selecting a target group of students in need of remediation in basic reading and/or mathematics, and for scheduling that group in compliance with the stated needs of the particular systems. During the 1987/88 school year the citywide test scores of 1,734 students were included in the analysis of improvements in reading performance, and the scores of 1,351 students were used to analyze mathematics performance improvements.

Tests used were the **Degrees of Reading Power (DRP)** for reading achievement and the **Metropolitan Achievement Test (MAT)** for mathematics performance. Each student's 1987 and 1988 mid-instructional scores compared using several statistical analysis. Only students for whom both 1987 and 1988 scores were available were included in the study. Students in grades eleven and twelve do not take DRP's, and students in grades nine through twelve do not take MAT's, thus participating students in those grades were not included in the study. Student groupings containing less than five subjects were also omitted from the analyses in which they occurred.

Matched T-tests were used to test for significant differences between students 1987 and 1988 DRP and MAT scores, and effect sizes for the mean differences between these generated. Effect sizes were calculated by dividing mean differences by their standard deviations. Effect sizes of one or greater thus indicate performance increases of a full standard deviation or more. Matched T-tests and effect sizes were used to compare both reading and mathematics scores for computer systems (programs) by grade levels by individual schools, for grade clusters (ie. elementary, junior high, high school) by student categories (ie. special education, Chapter 1, bilingual, remedial, general), and for grade clusters by student categories by CBI programs.

In addition, analyses of covariance were used to compare 1988 mean scores between various student groupings (ie. grade clusters, student categories, computer systems) to test for significant differences among these. 1987 scores were used as covariates to control for individual differences. ANCOVA's were also used to test for significant interactions between grade clusters and computer systems, and between grade clusters, student categories, and computer systems.

Results

Table 1 shows the results of matched T-test comparisons broken down by systems and schools and grades for reading scores. Table 2 shows the results of matched T-test comparisons broken down by systems and schools and grades for mathematics scores. These results show that, in general, students participating in the Computer Pilot Program showed significant increases in both reading and mathematics performance. An overall effect size of 0.8 was found across in reading improvements and an overall effect size of 0.9 was found across in mathematics improvements, indicating that, in general, such increases were educationally meaningful.

Table 1
EFFECT SIZES 1988 DRP Scores: System by School by Grade

SCHOOL		GR	N	1987	1988	X DIF	SD	ES
PRESCRIPTION LEARNING:	PS 59	4	11	34 8	40.1	5.3*	4.9	1.1
		5	20	43.3	59 6	16 3*	6.5	2.5
		6	8	49 1	54.1	5.0*	4 3	1 2
	IS 390	8	19	43.1	57.3	14 2*	4 8	3.0
CCC:	PS 152	3	18	56 0	70 0	14 0*	13.6	1 0
		4	41	31 [illegible]	44 0	12 3*	7 7	1 6
		5	44	33 3	49.8	16.5*	7.5	2.2
	PS 160	4	68	32.9	45.5	12.6*	7.9	1.6
WICAT:	PS 31	3	20	36 3	52.0	15 7*	10 8	1 5
		4	21	29.8	38.2	8.4*	6 9	1 2
		5	22	39 3	50 7	11 4*	6 5	1 8
AUTOSKILLS:	PS 246	4	71	20 6	28 7	8 1*	6 1	1 3
	IS 231	7	14	44 4	54.2	9.8*	5.1	1 9
		8	13	51.7	56 5	4 8*	6 4	0.8
ESC:	PS 332	3	21	26 2	37 4	11.2*	10.2	1 1
		4	18	21 6	28 7	7 1*	5 2	1 4
		5	17	33.1	43.9	10.8*	10 3	1 0
PC CLASS:	PS 142	3	20	29.4	45 8	16 4*	17 4	0 9
		6	24	45.0	51.7	6.7*	6.8	1 0
	JHS 141	7	10	52.4	57.2	4.8**	7.7	0.6
		8	106	57.2	63 1	4.9*	6.7	0.9
DEGEM:	PS 268	3	82	50.3	58.4	8.1*	13.3	0.6
		4	78	38.0	44.9	6.9*	6.5	1.1
		5	107	42.3	54.4	12 1*	8.8	1.4
		6	115	54.2	57.2	3.0*	6.7	0.5
	JHS 210	7	43	49 1	54.3	5.2*	7.7	0.7
		8	48	54.9	58.2	3.3*	5.9	0.6
	IS 252	7	64	49.6	54.9	5.3*	8.6	0.6
		8	26	56.6	59.4	2.8*	6.3	0.4
		9	20	56.2	58.9	2.7**	6.6	0.4
	John Jay HS	9	20	60.7	62.5	1.8	4.7	0.4
		10	77	59.9	61.9	2.0*	7 0	0.3
WASATCH:	PS 126	3	15	35.5	42.6	7.1*	9.9	0.7
		4	33	31.2	34 3	3.2*	6.6	0.5
		5	67	50 0	58.6	8.5*	8.5	1 0
		6	34	58.0	62.9	4.9*	7.2	0.7
	IS 117	7	52	50.9	52.3	1.4	11.3	0.1
		8	93	53.5	58 9	5.4*	5 9	0.9
		9	6	59.7	61.5	1.8	6.1	0.3
CNS:	JHS 189	7	37	56.8	62.6	5.8*	5.9	1 0
		9	23	57.4	60.8	3.4*	7 0	0.5
IDEAL:								
	Tilden HS	9	5	50.2	53.0	2.8	10.8	0.3
		10	17	59.2	63.2	4.0*	6.1	0.7
PLATO:	Prospect Heights HS	9	5	57 2	61.2	4 1*	7.7	0.5
		10	17	60.0	62.1	2.1	5.2	0.4
	South Bronx	9	51	57.2	59.1	1.9*	6.3	0.3
CCP:	Washington	9	22	56.0	55.5	-0 5	8.8	-0 1
	T Roosevelt	9	19	52.6	56.7	4.1*	5.5	0.9
PALS:	M L King HS	9	17	51.2	52.2	1.0	5.5	0.2
		10	6	51.7	53.5	1 8	7 1	0.3
	T Jefferson	9	10	49.8	55.1	5.3*	5.7	0 9
		10	10	58.5	49.4	0.9	6.4	0.1

* -- significant difference at p < .05 level
** -- significant difference at p < .10 level

Table 2
EFFECT SIZES: 1988 MAT Math Scores: System by School by Grade

SCHOOL	GR	N	1987	1988	MEAN DIF	SD	ES
CCC:							
PS 152	3	18	554.9	629.9	75.0*	19.1	3.9
	4	45	571.5	613.7	42.2*	23.6	1.8
	5	44	594.3	627.6	33.2*	19.1	1.7
PS 160	4	68	574.4	615.5	41.1*	21.1	1.9
WICAT:							
PS 31	3	20	524.9	569.2	44.3*	23.4	1.9
	4	19	554.5	590.7	36.2*	16.1	2.2
	5	23	574.6	611.0	36.3*	12.3	3.0
DEGEM							
PS 225	3	12	508.0	541.6	33.6*	23.1	1.5
	4	71	563.1	602.6	39.5*	17.5	2.3
	5	33	588.0	603.7	15.7*	17.6	0.9
	6	23	594.1	622.5	28.4*	21.8	1.3
PS 268	3	87	572.0	593.1	21.1*	33.8	0.6
	4	77	588.3	619.5	31.1*	19.7	1.6
	5	108	612.8	647.7	35.0*	23.0	1.5
	6	113	633.8	655.5	21.7*	18.0	1.2
JHS 210	7	46	617.9	628.5	10.6**	16.8	0.6
	8	43	630.8	646.8	16.0**	18.6	0.9
IS 252	7	66	617.8	621.9	4.1**	15.9	0.3
	8	21	624.2	629.1	4.9	16.5	0.3
PC CLASS:							
PS 142	3	25	512.4	568.9	56.4*	42.7	1.3
	6	28	600.9	636.7	35.8*	12.4	2.9
JHS 141	7	8	620.9	629.9	9.0	19.3	0.5
	8	91	640.1	649.0	8.9**	14.4	0.6
ESC:							
PS 332	3	22	532.8	3556.7	23.9*	26.0	0.9
	4	15	542.0	2559.7	17.7*	17.2	1.0
	5	18	587.8	4603.4	15.7*	23.6	0.7
PRESCRIPTION LEARNING:							
IS 390	8	17	602.1	621.5	19.4**	22.9	0.8
WASATCH:							
PS 126	3	17	554.4	560.0	5.6	21.0	0.3
	4	35	564.1	579.4	15.3*	22.1	0.7
	5	65	617.2	642.5	25.2*	21.8	1.2
	6	34	642.7	670.6	28.0*	19.7	1.4
IS 117	7	55	626.5	621.4	-5.0	122.4	-0.2
	8	88	621.4	633.6	12.2**	14.5	0.8
CNS:							
JHS 189	7	39	656.6	653.4	-3.2	20.8	-0.2

* -- significant difference at $p < .01$ level
** -- significant difference at $p < .05$ level

Notice that these findings indicate that the CBI programs tested were, in general equally effective in producing increases in students' reading and mathematics performance. Such results argue against commonly held notions (White, 1986; Niemiec & Walberg, 1987) that CBI is a more effective means for delivering mathematics instruction than for delivering reading instruction, at least among the educationally disadvantaged student population tested.

Notice also that effect sizes decrease with advancing grade levels. Effect sizes in reading break down to 1.1 for elementary school students, 0.7 for junior high students, and 0.3 for high school students. In mathematics, effect sizes break down to 1.2 for elementary students and 0.4 for junior high students. To test for the statistical significance of this effect, analyses of covariance were used to compare the 1988 scores of students in three grade clusters -- elementary, junior high, and high school -- for reading, and two grade clusters -- elementary and junior high school -- for mathematics, using 1987 scores as a covariate to control for individual differences. Table 3 shows the results of the analysis of reading scores; Table 4 shows the the results of the analysis of mathematics scores.

Table 3
ANCOVA TABLE*
1988 Citywide Degrees of Reading Power (DRP) Scores by Grade Clusters

	SS	DF	MS	F	P
W/IN CELL	84244.76	1583	53.22		
REGRESSION	148676.19	1	148676.19	2793.70	.000
GRADCLUST	1375.96	2	687.98	12.93	.000

*1987 DRP reading scores as covariate

Table 4
ANCOVA TABLE*
1988 Scaled Metropolitan Achievement Test (MAT) Math Scores by Grade Clusters

	SS	DF	MS	F	P
W/IN CELL	587073.01	1348	435.51		
REGRESSION	1481310.94	1	1481310.94	3401.29	.000
GRADCLUST	53823.15	1	53823.15	123.59	.000

*1987 MAT math scores as covariate

The results reveal significant differences between grade clusters in both reading ($F_{1, 1583}$ = 12.93, $p < .01$) and mathematics ($F_{1,1348}$ = 123.59, $p < .01$). These findings corroborate Kulik's (1981) finding of an inverse relationship between students' instructional level and performance gains resulting from CBI use. They are particularly meaningful because they corroborate the results of his meta-analysis within a single study and with respect to an educationally disadvantaged student population.

To test the parameters of this relationship, several comparisons were made involving student categories. Analysis of covariance were used to compare 1988 mean scores in both reading and mathematics among students in five student categories -- special education, Chapter 1, bilingual, remedial, and general education -- which were understood as representing, in that order, increasingly advanced levels of instruction. 1987 mean scores were used as the covariate. The results of these analyses are given in Tables 5 and 6. They indicate significant differences in performance gain between student categories in both reading ($F_{4,1581}$ = 11.40, $p < .01$) and mathematics ($F_{4,1345}$ = 24,74, $p < .01$). Table 7 shows effect sizes by grade clusters and student categories for reading gains, and Table 8 shows effect sizes by grade clusters and student categories for gains in mathematics. Notice that, especially within the lower grades, an inverse relationship between instructional level and achievement can be quite clearly distinguished. Special education students benefited most from CBI use at all grade levels, and remedial and general education students benefited least at most grade levels. The inverse relationship seems clearer, however, among students in the lower grades.

Table 5
ANCOVA TABLE*
1988 Citywide Degrees of Reading Power (DRP) Scores by Student Categories

	SS	DF	MS	F	P
W/IN CELL	83221.31	1581	52.64		
REGRESSION	176310.06	1	176310.06	3349.46	.000
STUDCAT	2399.42	4	599.85	11.40	.000

*1987 DRP reading scores as covariate

Table 6
ANCOVA TABLE*
1988 Scaled Metropolitan Achievement Test (MAT) Math Scores by Student Categories

	SS	DF	MS	F	P
W/IN CELL	596979.00	1345	443.85		
REGRESSION	1180858.49	1	1180858.49	2660.49	.000
STUDCAT	43917.16	4	10979.29	24.74	.000

*1987 MAT math scores as covariate

Table 7
EFFECT SIZES
1988 DRP Scores by Grade Clusters and Student Categories

STUD CAT	N	1987	1988	MEAN DIF	SD	ES
ELEMENTARY:						
Special Ed	10	32.8	46.9	14.1*	6.6	2.1
Chapter 1	289	31.6	40.2	8.6*	7.4	1.2
Bilingual	46	37.6	49.0	11.4*	9.6	1.1
General	256	50.9	58.3	7.4*	8.6	0.9
Remedial	104	38.9	45.9	8.0*	8.7	0.8
JUNIOR HIGH:						
Special Ed	19	43.1	57.3	14.2**	4.8	3.0
Chapter 1	266	51.6	56.5	4.9*	7.4	0.7
Remedial	241	54.9	59.8	4.9*	6.9	0.7
General	44	59.6	62.3	2.7	9.7	0.3
HIGH SCHOOL:						
Remedial	21	57.9	61.3	3.4*	4.9	0.7
Chapter 1	296	56.4	58.6	2.2	6.8	0.3

Table 8
EFFECT SIZES
1988 MAT Math Scores by Grade Clusters and Student Categories

STUD CAT	N	1987	1988	MEAN DIF	SD	ES
ELEMENTARY:						
Special Ed	11	567.5	604.1	36.5*	25.6	1.4
Chapter 1	371	565.8	595.8	30.0*	22.5	1.3
Bilingual	58	578.9	610.4	31.4*	26.3	1.2
General	296	621.1	649.5	28.4*	25.3	1.1
Remedial	128	582.9	606.1	23.2*	23.1	1.0
JUNIOR HIGH:						
Special Ed	17	602.1	621.5	19.4**	22.9	0.8
Remedial	202	632.4	642.0	9.6*	16.7	0.6
Chapter 1	242	619.9	626.7	6.7*	17.1	0.4
General	41	653.4	648.2	-5.2	25.2	-0.2

* – significant difference at p < .01 level
** – significant difference at p < .05 level

To test for the significance of these seemingly different patterns of student gains, analyses of covariance were used to compare 1988 mean scores in both reading and mathematics among students by grade clusters and student categories using 1987 mean scores as the covariate (Tables 9 and 10): The results indeed reveal significant interactions between grade clusters and student categories in both reading ($F_{5,1574} = 2.92$, $p < .05$) and mathematics ($F_{4,1240} = 8.66$, $p < .01$), indicating differential patterns of achievement among student categories within differing grade clusters. Effect size data indicates that the major source of such differences involves the differential ranking of Chapter 1 and remedial students at differing grade levels. In general, however, findings show that an inverse relationship between instructional level and achievement gains resulting from CBI use holds not only between grade levels but between student categories within grade levels.

Table 9
ANCOVA TABLE*
1988 DRP Scores by Grade Cluster and Student Catgory

	SS	DF	MS	F	P
W/IN CELL	82162.10	1574	52.20		
REGRESSION	102165.11	1	1021165.11	1957.20	.000
GRDCLUST	190.46	2	95.23	1.82	.162
STUDCAT	189.18	4	47.30	.91	.460
GC X SC	761.41	5	152.28	2.92	.013

*1987 DRP reading scores as covariate

Table 10
ANCOVA TABLE*
1988 Scaled MAT Math Scores by Grade Cluster and Student Catgory

	SS	DF	MS	F	P
W/IN CELL	560357.78	1340	131.63		
REGRESSION	975156.66	1	975156.66	2331.92	.000
GRDCLUST	1350.77	1	1350.77	3.23	.073
STUDCAT	1878.54	4	469.64	1.12	.344
GC X SC	14525.65	4	3631.41	8.68	.000

*1987 MAT math scores as covariate

Table 11 shows the analysis of covariance comparing 1988 mean scores in reading between students using differing CBI programs, and Table 12 shows the analysis of covariance comparing 1988 mean scores in mathematics between students using differing CBI programs. In both cases, 1987 mean scores were used as the covariate to control for individual differences. The results reveal the differential effects of particular computer systems as indicated by significant differences in students' performance increases between computer systems in both reading ($F_{12,1716} = 11.98$, $p < .01$), and mathematics ($F_{8,1341} = 13.00$, $p < .01$). Because, however, certain CBI programs were only used at particular grade levels, and, as we have seen, particular grade levels experienced significantly greater performance increases than others, seeming differences between systems may be the result of differences between grade clusters rather than real differences between systems. For example, CCC and Wicat, the programs with the seemingly greatest effects, were only used at the elementary level, the grade level exhibiting the largest effect sizes. On the other hand, these programs were also most effective within that level in both reading and mathematics, an indication that the programs themselves were at least partially responsible for their successes.

Table 11
ANCOVA TABLE*
1988 Citywide Degrees of Reading Power (DRP) Scores by Computer Systems

	SS	DF	MS	F	P
W/IN CELL	172496.93	1716	100.52		
REGRESSION	158533.29	1	158533.29	1577.09	.000
COMPSYS	14457.13	12	1204.76	11.98	.000

*1987 DRP reading scores as covariate

Table 12
ANCOVA TABLE*
1988 Scaled Metropolitan Achievement Test (MAT) Math Scores by Computer Systems

	SS	DF	MS	F	P
W/IN CELL	594766.97	1341	443.52		
REGRESSION	1169511.28	1	1169511.30	2636.86	.000
COMPSYS	46129.19	8	5766.15	13.00	.000

*1987 MAT math scores as covariate

To examine this issue in greater detail, the differential effectiveness of particular CBI systems within grade clusters was tested using analyses of covariance with 1987 mean scores as covariates (Tables 15 and 16). A significant interaction between computer systems and grade clusters in reading ($F_{7,1567} = 2.80$, $p < .01$), but not in mathematics ($F_{3,1337} = .73$, $p > .10$) was found, indicating that particular CBI programs were more effective at certain grade levels than at others for delivering reading, but not mathematics, instruction. In particular, effect size data reveal that the PC Class and Autoskills systems were among the least effective of the programs tested at the elementary level for the delivery of reading instruction, but among the most effective with junior high students. Because these results run counter to the general inverse relationship between achievement gains and instructional level, they should be seriously considered.

Table 15
ANCOVA TABLE*
1988 DRP Scores by Grade Cluster and Computer Systems

	SS	DF	MS	F	P
W/IN CELL	80878.48	1567	51.61		
REGRESSION	100544.20	1	100544.20	1948.02	.000
GRDCLUST	0.0	2	.00	.00	1.000
COMPSYS	1791.56	12	149.30	2.89	.001
GC X CS	1010.28	7	144.33	2.80	.007

*1987 DRP reading scores as covariate

Table 16
ANCOVA TABLE*
1988 Scaled MAT Math Scores by Grade Cluster and Computer Systems

	SS	DF	MS	F	P
W/IN CELL	555773.43	1337	415.69		
REGRESSION	1125467.70	1	1125467.70	2707.49	.000
GRDCLUST	2320.99	1	2320.99	5.58	.018
COMPSYS	28043.29	8	3505.41	8.43	.000
GC X CS	909.22	3	303.07	.73	.535

*1987 MAT math scores as covariate

Tables 17 and 18 show mean differences and effect sizes for computer systems by student categories and grade clusters. Notice that in reading (Table 17), students using the CCC, Prescription Learning, and Wicat systems evidenced the greatest effect sizes in all student categories at the elementary level, and that students using the Prescription Learning, Autoskills, and PC Class systems evidenced the greatest effect sizes across student categories at the junior high school level. Ideal and Plato were most effective across categories of high school students. The differential effectiveness of the PC Class and Autoskills programs for varying grade levels is also evident. In mathematics (Table 18), students using the CCC, Prescription Learning, and Wicat programs again evidenced the greatest effect sizes at the elementary level, and the use of Perscription Learning, PC Class, and Degem resulted in the greatest performance increases at the junior high level.

Table 17
EFFECT SIZES
1988 DRP Scores: Grade Cluster by Student Category by Computer System

SYSTEM	N	1987	1988	MEANDIF	SD	ES
ELEMENTARY:						
SPECIAL ED:						
Prescription L	6	36.8	53.5	16.7*	5.0	3.3
CHAPTER 1:						
CCC	9	19.6	32.7	13.1*	6.4	2.0
Wicat	45	34.3	44.5	10.2*	6.8	1.5
Autoskills	71	20.6	28.7	8.2*	6.1	1.3
Prescription L	6	39.0	47.0	8.0*	6.4	1.3
ESC	37	27.1	36.6	9.5*	8.4	1.1
Degem	130	38.4	46.1	7.7*	8.0	1.0
BILINGUAL:						
CCC	6	20.2	40.2	20.0*	8.0	2.5
Degem	10	40.8	50.3	9.5*	3.9	2.4
Wasatch	23	41.6	53.0	11.4*	11.0	1.0
PC Class	7	35.0	41 7	6.7***	8.2	0.8
GENERAL:						
CCC	49	37.5	49.0	11.5*	8.0	1.4
Degem	174	52.2	59.1	6.9*	8.8	0.8
Wasatch	72	57.5	63.3	5.8*	6.9	0.8
REMEDIAL:						
Prescription L	27	43.9	54.2	10.3*	8.4	1.2
Degem	33	44.9	52.0	7.1*	10.0	0.7
Wasatch	42	31.4	36.1	4.7*	7.2	0.7
JUNIOR HIGH:						
SPECIAL ED:						
Prescription L	19	43.1	57.3	14.2**	4.8	3.0
CHAPTER 1:						
Autoskills	28	47.5	55.3	7.8*	6.3	1.2
Wasatch	128	51.7	56.7	4.9*	7.3	0.7
Degem	110	52.5	56.7	4.2*	7.8	0.5
REMEDIAL:						
PC Class	108	57.2	62.8	5.6*	6.9	0.8
CNS	39	54.7	59.4	4.7*	7.0	0.7
Degem	90	52.4	56.6	4.3*	6.9	0.6
GENERAL:						
PC Class	8	50.9	58.8	7.9*	5.7	1.3
CNS	17	63.2	68.8	5.5*	4.9	1.1
Wasatch	19	60.1	57.9	-2.2	12.2	-0.2
HIGHSCHOOL:						
REMEDIAL:						
Ideal	11	52.6	54.6	4.3*	5.2	0.8
Degem	7	60.6	64.9	2.0	4.2	0.5
CHAPTER 1:						
Plato	102	57.3	59.9	2.6*	7.0	0.4
Ideal	11	53.6	56.8	3.2	8.8	0.4
PALS	43	50.3	52.4	2.1**	6.1	0.3
Degem	90	60.7	62.6	1.9*	6.8	0.3
CCP	39	54.1	55.5	1.4	9.2	0.2

* -- significant difference at $p < .01$ level
** -- significant difference at $p < .05$ level
*** -- significant difference at $p < .10$ level

Table 18
EFFECT SIZES
1988 MAT Math Scores: Grade Cluster by Student Category by Computer System

SYSTEM	N	1987	1988	MEAN DIF	SD	ES
ELEMENTARY:						
SPECIAL ED:						
Prescription L	7	585.1	614.4	29.3*	19.0	1.5
CHAPTER 1:						
Prescription L	7	590.0	630.9	40.9*	13.2	3.1
Wicat	62	552.4	591.3	138.9*	17.8	2.2
Degem	166	581.8	610.9	29.2*	22.6	1.3
CCC	9	551.4	584.2	32.8*	25.6	1.3
ESC	36	553.4	574.0	20.6*	23.3	0.9
BILINGUAL:						
CCC	6	548.8	593.5	44.7*	21.3	2.1
Degem	12	589.4	613.9	24.5*	17.3	1.4
PC Class	17	550.9	589.6	38.6*	33.0	1.2
Wasatch	22	602.4	629.9	27.5*	24.6	1.1
GENERAL:						
CCC	50	583.6	625.4	41.8*	20.6	2.0
Wasatch	72	636.4	661.2	24.8*	19.9	1.2
Degem	174	625.5	651.6	26.0*	27.3	1.0
REMEDIAL:						
Perscription L	28	602.1	634.9	32.8*	20.7	1.6
Degem	42	598.0	625.7	27.7*	20.7	1.3
Wasatch	57	562.5	577.2	14.6*	23.0	0.6
JUNIOR HIGH:						
SPECIAL ED:						
Prescription L	17	602.1	621.5	19.4**	22.9	0.8
REMEDIAL:						
Degem	88	624.6	637.7	13.1*	17.9	0.7
PC Class	92	639.7	648.2	8.5*	14.3	0.6
CNS	18	636.0	635.5	-0.5	17.9	0.0
CHAPTER 1:						
Wasatch	127	622.3	630.0	7.7*	17.5	0.4
Degem	88	619.1	623.9	4.8*	16.5	0.3
GENERAL:						
PC Class	7	623.4	638.1	14.7	20.4	0.7
CNS	17	684.2	675.5	-8.7	21.6	-0.4
Wasatch	17	635.0	625.0	-10.0	27.5	-0.4

* – significant difference at p < .01 level

Discussion

The results of the analyses indicate that CBI can indeed be an effective means for delivering remedial instruction in reading and mathematics to educationally disadvantaged students. Significant increases in both reading and mathematics scores were found for the majority of students participating in the Computer Pilot Program. That such increases were educationally meaningful is demonstrated by their effect sizes -- 0.8 for reading and 0.9 for mathematics. These results are particularly meaningful given that they were culled from mostly start-up implementations operating within a very large and diverse educational system, and so were subject to all the constraints attendent upon such an effort. Included among such constraints were technical problems with particular implementations, a perceived lack of sufficient training among a majority of the staff participating in the program, minimal student involvement with many of the CBI programs, and, in certain cases, the newness of the programs themselves. An apparent lack of correlation between the achievement goals of the CBI programs tested and those of the City of New York, demonstrated in a regression analysis comparing students' system-embedded gains with their scores on citywide tests, may indicate another problem area. Indications are, then, that results could be even more positive as faculty and students adjust to the use of this new and different educational medium.

Our findings also suggest that CBI was as effective a medium for the delivery of instruction in reading as it was for the delivery of mathematics instruction to the educationally disadvantaged student population we surveyed. While overall effect sizes for increases in mathematics were slightly higher than those for reading performance, a larger percentage of students advanced to grade level or above in reading than in mathematics. Likewise, differences seen in interactions between content areas and other variables (ie. grade clusters, student categories, and computer systems) tended to balance themselves out. Such results contradict commonly held beliefs asserting that CBI is a more effective medium for supporting mathematics instruction than for supporting instruction in reading (Niemiec & Walberg, 1987; White, 1986). They argue instead that CBI can be an effective means for providing remedial instruction in both areas, at least among educationally disadvantaged populations.

Niemiec and Walberg (1987) suggest four reasons for CBI's particular effectiveness among educationally disadvantaged student populations. They contend that CBI is less threatening than instruction relying on classroom recitiation and that such lack of threat may be more meaningful to the educationally disadvantaged; that educationally disadvantaged students may benefit more from the extensive drill and practice exercises typically offered in CBI programs; that the diagnostic procedures integral to most such programs may benefit educationally disadvantaged students more than others because they are more likely to need specific remediation; and that extra teaching resources, which tend to be more useful to the educationally disadvantaged because they need more academic support, may be available to students involved with CBI programs. Our interviews with students and teachers participating in the Computer Pilot Program support all four arguements.

When asked how learning on computers differed from their regular classroom activities, the students we interviewed overwhelming responded that learning on computers was less threatening. "I don't have to talk," "I don't have to write," "My mistakes aren't embarrassing," " It doesn't talk back," and "The computer doesn't yell at me" were typical of the answers we received. Not only teachers, but many students we interviewed stated that the large amount of practice they received was very helpful. "The computer calls on me every time," one student commented. "You have to think more," another said. Students interviewed also believed that the immediate and informative feedback typically accompanying CBI drill and practice exercises made them especially useful. Participating teachers we interviewed believed that the diagnostic procedures offered by the CBI programs we evaluated were among their most useful features. They thought that the feedback from such procedures had made them more aware of students' individual strengths and weakness thus helping them to target specific areas where extra remediation was needed. Finally, it is unquestionably the case that extra teaching resources necessarily accompany CBI programs because the programs themselves are an important extra resource. Students reported that the programs were responsive their needs. Teachers reported that they freed them, not only from routine bookeeping and disciplinary chores, but from general lecturing as well, thus allowing them to devote more individual attention to their students. In addition, the average student/teacher ratio in the program implementations we evaluated was 15/1, considerably lower than those common in regular classrooms in the New York City system.

The results of our analyses also show significant differences between grade levels for both reading and mathematics performance gains. They thus support Kulik's (1981) assertion that an inverse relationship exists between instructional level and achievement gains resulting from CBI use. The effect sizes of student gains were greater for elementary students than for junior high students and greater for junior high students than for high school students.

Such findings indicate that the inverse relationship between grade level and CBI gains which Kulik found among general student populations is likewise true of educationally disadvantaged populations.

The picture is not quite so clear when instructional level is considered in terms of student categories within grade levels. Indeed, significant interactions between grade clusters and student categories were found for both reading and mathematics. At the elementary level for both reading and mathematics, students at the lower levels of instruction (special education, Chapter1, and bilingual) experienced greater achievement score increases than students at higher levels of instruction (remedial, general.) At the junior high level for reading, special education students showed the largest performance gains and general education students showed the smallest gains, but the gains evidenced by Chapter 1 and remedial students were essentially the same. At the junior high level in mathematics, special education students again showed the greatest achievement gains and general education students, the least, but remedial students showed greater gains than those enrolled in Chapter 1 programs. The same is true of high school students' reading performance gains.

It is not clear why the patterns of relationships among student categories thus seem to change with changes in grade levels. It may be that the characteristics of students making up the Chapter 1 and remedial categories change as grade levels increase. It is interesting to note in this regard that the numbers of students entering the Computer Pilot Program at or above grade level seem to decline with increasing grade levels. On the other hand, it may be that the needs of Chapter 1 and/or remedial students differ at differing grade levels. It could be, for example, that remedial students at the upper grade levels are particularly in need of the kinds of drill and practice abundantly available in most CBI programs, whereas at lower grade levels, remedial students are in greater need of instruction concerned with other things. In any case, the findings indicate that the use of CBI was most effective for special education students and least effective for general education students at all grade levels. CBI was more effective for Chapter 1 and bilingual than for remedial students at the elementary levels, but that it was more effective for remedial than for Chapter 1 students at the upper grade levels. In general, however, they indicate an inverse relationship between instructional level and performance gains resulting from CBI use even with grade level held constant.

The explanation for this inverse relationship may simply be that CBI is a more effective delivery system for students at lower instructional levels. It is more likely that the design of current programs better supports the sort of content addressed at lower instructional levels. While the simple tutorial and drill and practice routines common to most systems seem particularly effective, not only for developing needed skills, but for diagnosing skill deficiencies at such levels, the problem solving skills inherent in higher level reading comprehension and mathematical problem solving may neither be so easily developed, nor the lack of such skills effectively diagnosed, by instructional models of this sort. In any case, the results clearly argue that the most effective use of CBI programs among the population tested was in the elementary grades and among special education students, that the least effective use of them was among high school and general education students.

Results concerning the relative effectiveness of the differing CBI programs were difficult to analyze because the grade levels and student categories with which they were tested, variables which significantly effected program success, differed among differing programs. Differences in staffing and implementation characteristics and in the larger educational environments found among participating schools also contributed to problems surrounding the analysis of program effectiveness, such that the extent to which the differential effectiveness of the varying programs may be attributed to factors external to these programs could not be determined. Participation in the CCC and Wicat programs, for example, resulted in increases in both reading and mathematics achievement scores that were among the largest found in the entire Computer Pilot Program. These programs, however, were tested only at the elementary level, thus while their effectiveness at this level was unquestionably demonstrated, their relative effectiveness was not necessarily shown. Likewise, some of the largest increases in the entire evaluation were shown by students using the Perscription Learning program, but these were all special education students.

Use of the Prescription Learning program, in fact, resulted in large achievement increases at both the elementary and junior high levels, indicating its effectiveness at both these levels. The PC Class program was another whose use resulted in large achievement gains in both reading and mathematics at the junior high level. Indeed, this program appears to have been more effective at this level than at the elementary level. As such a finding contradicts the general tendency for programs to be more effective at lower instructional levels, we might assume it says something about the program itself. The PC Class system, however, is a generic learning by objectives program which can utilize any IBM PC software.

As it is likely that differing software programs were utilized in different implementations, it is more reasonable to assume that such performance variations resulted rather from differences in software and not some developmental differential in what is essentially a delivery system.

Autoskills, which is just a reading program, was also very effective at the junior high but not at the elementary level, and is most likely the source of the significant interaction found between CBI programs and grade clusters for reading but not mathematics. This difference between grade levels seems also to have resulted from implementation differences rather than the program itself as Autoskills was used alone at the elementary level, but at the junior high level was integrated into a total language arts program involving other Icon language arts software as well as off-computer reading and writing.

At the high school level, for which only reading scores were available, the Ideal and Plato systems resulted in the greatest increases in student achievement. Because achievement gains were so low and mathematics scores were not available at this level, the effectiveness of these systems among high school populations was suggested but not clearly indicated in the findings.

Certain systems seem to have been more effective in providing instruction in one content area than the other. Degem, for example, appears to have been reasonably effective for providing mathematics instruction to students at all grade levels, but not very effective in providing reading instruction at any level. On the other hand, use of the ESC system, which occurred only at the elementary level, resulted in greater gains in reading than in mathematics. It was not, however, a leader in either content area. The CNS system, which was used only at the junior high level seems to have been somewhat effective in providing reading instruction, but appears to have actually been counterproductive in the area of mathematics. The Wasatch system appears to have only been effective in providing reading instruction, and then only at the elementary level. Wasatch, however, is not a learning-by-objectives program like most of the others, but rather a process-oriented program. Thus it may be that teachers need time to adjust to this type of program before they can make effective use of it.

The effectiveness of the PALS and CCP systems which were designed specifically for high school students seems doubtful, especially considering the large amounts of student and faculty time they demand. Because, however, they were only used with high school students whose achievement gains were generally low, it is not possible to reach a conclusion concerning these systems.

Conclusions

We can conclude, however, that CBI programs can be effectively used to deliver remedial instruction in reading and mathematics to educationally disadvantaged inner city students, that they can be as effective for delivering instruction in reading as they are for delivering mathematics instruction to such populations, and that among such populations an inverse relationship exists between instructional level and CBI effectiveness as measured in terms of achievement gains. In addition, we can conclude that the CCC, Wicat, and Prescription Learning programs can be good vehicles for the delivery of remedial instruction in both reading and mathematics to elementary school students, and that the Presription Learning, Autoskills, and PC Class programs can be used effectively with junior high students. Indications are that the Ideal and Plato programs might be useful for providing high school students with basic skills remediation, and that the Degem program may be well adapted for mathematics remediation at all instructional levels. Continued investigation of all programs at all levels is, of course, needed to better determine their relative efficacies.

Other interesting questions needing further study include the long term effects of CBI use, issues of transfer from computer-based learning to other media, and changes in the structure of the overall educational environment resulting from large scale CBI use. Of particular interest are educational effects other than achievement gains resulting from involvement with CBI programs. Increased student motivation, for example, improved attendance, lower drop-out rates, and better student attitudes toward school and learning might be more beneficial to educationally disadvantaged students in the long run than short term academic achievement gains. Student perceptions of increased control over their own learly clearly deserve further study. For the present, however, the pressing realities of the crisis in education, especially among educationally disadvantaged inner city populations, together with the demonstrated efficacy of at least certain CBI programs, argue quite strongly for their adoption for the delivery of basic skills remediation to such populations, particularly at lower levels of instruction.

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